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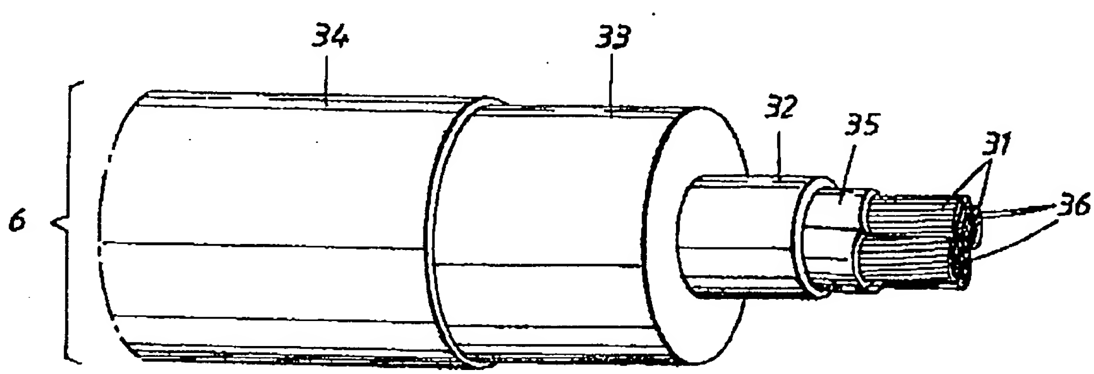

(57) Abstract

In a plant intended for driving traction motors e.g. railway locomotives or motor coaches, and which possibly comprises one or more electric machines provided with insulated conductors, the magnetic circuit in the traction motor(s) and/or in at least one of the other electric machines is connected directly to a high supply voltage of 21-800 kV, preferably higher than 36 kV. The insulation in each traction motor and other electric machines is built up of a cable (6) forming its winding, said cable (6) comprising one or more current-carrying conductors (31) with a number of strands (36), surrounded by at least two semiconducting layers (32, 37) and intermediate insulating layers (36). The traction motor(s) may be connected to the distribution network supplying the supply line of the railway without any other electric machine connected between, or via one or more of said other electric machines. The locomotive/motor coach may thus be constructed with only traction motor(s) without any other electric machine.

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AN ELECTRIC DRIVE SYSTEM FOR VEHICLES

Technical field:

The present invention relates to electric machines intended for connection to distribution or transmission networks, hereinafter called power networks. More specifically the invention relates to a plant for driving traction motors, e.g. railway locomotives and motor coaches, in which the traction motor and/or other electric machines included in the plant are provided with a magnetic circuit comprising a magnetic core and at least one winding.

In conjunction with this the invention relates in the first place to an electric drive system of the type described in the preamble to claim 1, in the second place to an electric power transmission means of the type described in the preamble to claim 30, in the third place to a procedure for electric power transmission of the type described in the preamble to claim 35, in the fourth place to an electric machine of the type described in the preamble to claim 36 and in the fifth place to a vehicle of the type described in the preamble to claim 42.

Background art:

The magnetic circuit in electric machines usually comprises a laminated core, e.g. of sheet steel with a welded construction. To provide ventilation and cooling the core is often divided into stacks with radial and/or axial ventilation ducts. For larger machines the laminations are punched out in segments which are attached to the frame of the machine, the laminated core being held together by pressure fingers and pressure rings. The winding of the magnetic circuit is disposed in slots in the core, the slots generally having a cross section in the shape of a rectangle or trapezium.

In multi-phase electric machines the windings are made as either single or double layer windings. With single layer windings there is only one coil side per slot, whereas with double layer windings there are two coil sides per slot. By coil side is meant one or more conductors combined vertically or horizontally and provided with a common coil insulation, i.e. an insulation designed to withstand the rated voltage of the machine to earth.

Double-layer windings are generally made as diamond windings whereas single layer windings in the present context can be made as diamond or flat windings. Only one (possibly two) coil width

exists in diamond windings whereas flat windings are made as concentric windings, i.e. with widely varying coil width. By coil width is meant the distance in arc dimension between two coil sides pertaining to the same coil.

Normally all large machines are made with double-layer winding and coils of the same size. Each coil is placed with one side in one layer and the other side in the other layer. This means that all coils cross each other in the coil end. If there are more than two layers these crossings complicate the winding work and the coil end is less satisfactory.

For historical reasons a number of supply systems with different voltage and frequency have been developed for railway operation. Once a system has become established in an area, changing to another system entails vast expense and disturbance in operation. In principle there are six standard solutions for supply voltages, three of which are direct voltage systems and three alternating voltage systems. This has meant that many traction vehicles (locomotives and motor coaches) and passenger coaches must be built for more than one supply system. Locomotives and coaches for integrated traffic between different countries exist today which can manage up to four different supply systems.

Electric energy for track supply can either be taken from the general distribution network or be generated in power stations run by the railway. The arrangements will differ depending on whether the supply is alternating or direct current tension. In the case of direct current electrification rectifier stations are required for conversion from the alternating voltage supplied by the public distribution network. These rectifier stations supply direct voltage at certain points along the railway. In the case of alternating current electrification with industrial frequency (50 or 60 Hz) only transformers are necessary at certain points. This is the simplest and least expensive solution and has the lowest power losses. In the case of electrification with low-frequency alternating current ($16^2/3$ or 25 Hz), converter stations are required to convert the voltage from the industrial frequency of the public distribution network, or special power stations and special distribution networks for the low-frequency alternating current.

Direct-voltage electrification was chosen originally because a suitable and simply controlled motor, the series-excited direct current motor, was available. Previously three-phase alternating voltage was converted to direct voltage with the aid of rotating

converters or mercury arc rectifiers, but nowadays the conversion is usually carried out with 6 or 12-pulse relays.

The direct voltage system has the advantage that the current can be used directly in direct current motors. No heavy transformer is required in the vehicle to step-down the voltage as is the case with alternating voltage. Vehicles supplied with direct voltage are therefore somewhat less expensive and easier to produce. The low direct voltage is an advantage from the safety aspect (for instance in underground railways where power busbars are used which may sometimes be exposed).

The drawback with direct voltage operation is primarily the low voltage which means that the current, and consequently the voltage drop and losses, are considerable. This must be compensated by large conductor areas and closely spaced rectifier stations (normally less than 10 km between stations). This results in expensive plants. The drawbacks are particularly noticeable at high power such as with high-speed traffic. Rectifier stations with high power must be built close together, and are only used during the short time the train passes the supply station in question.

Before it became possible to use industrial frequency (50 or 60 Hz) for traction motors, the first alternating voltage systems were electrified with low-frequency voltage ($16^2/3$ or 25 Hz). The traction motor used for a long time in such systems was a single-phase series commutator motor, also known as a single-phase traction motor. This functions almost like a direct current motor except that both field and rotor current are reversed every half period since it is supplied with alternating current. To get the commutation to function without damaging over-voltages or electric arcs, low frequency and motors with low speed had to be chosen.

The main advantage with alternating systems as opposed to direct current systems is that the alternating voltage can be transformed (even though direct voltage can nowadays be transformed with so-called choppers). It is thus possible to maintain a relatively high voltage on the overhead conductor in relation to the voltage with which the motor operates. Due to the high voltage in the overhead conductor the current becomes lower, thus giving better power transmission ability and lower losses in the line network. Supply stations can be located rather far apart (60-120 km). A drawback is, however, that the traction motors are large and the control technology is complication.

Another drawback is the need for frequency converters where motor generators would normally be used, i.e. generally a 50 Hz synchronous motor, which drives a single-phase $16^2/3$ Hz synchronous generator. The motor has three times as many poles as the generator. The rotating converters are built for a rather low nominal voltage (6 kV) so as to avoid the insulation having to be too strong. Transformers are therefore required both before and after the converters. Several converters are usually operated in parallel in the same plant.

The rotating converters can produce reactive power which is able to compensate the reactive power losses arising in the overhead conductor network and in the vehicle. The rotating converter also provides electric separation between the public distribution network and the overhead conductor system.

The main drawback of rotating converters is that start-up of the large synchronous machines is time-consuming and phasing in is complicated. It must be possible to satisfy a sudden demand for power. The machines must therefore be run as reserves at no load or with lower power for long periods. Another drawback is the energy losses which are partly caused by the above-mentioned operation at no load.

In new installations the rotating converters have been replaced by static converters. Static converters are inexpensive in initial outlay and in maintenance. They also offer advantages in quicker starts and lower energy losses. However, the harmonics are higher on both the three-phase and the single-phase side. Furthermore, static converters are unable to generate reactive power to compensate voltage drops caused by inductive load.

As is clear from the above, the various systems used for electrically operated railways are relatively complicated and expensive.

Machines of the above-mentioned type, with conventional stator winding, cannot be connected to a high-voltage network at e.g. 145 kV without the use of a transformer to lower the voltage. The use of a motor in this way, connected to the high-voltage network via a transformer, entails a number of drawbacks as compared with if the motor could be connected directly to the high-voltage network. The following drawbacks may be noted, among others:

- the transformer is expensive, increases transport costs and requires space
- the transformer lowers the efficiency of the system

- the transformer consumes reactive power
- a conventional transformer contains oil, with the associated risks
- involves sensitive operation since the motor, via the transformer, works against a weaker network.

Description of the invention:

The object of the present invention is to provide a drive system and components therefor for electric railway operation and the like, which solves some of the problems inherent in known systems in this area.

This object is achieved according to the invention in the first place in that an electric drive system of the type described in the preamble to claim 1 is given the special features defined in the characterizing part of this claim, in the second place in that an electric power transmission means of the type described in the preamble to claim 30 is given the special features defined in the characterizing part of this claim, in the third place in that a procedure of the type described in the preamble to claim 35 is given the special features defined in the characterizing part of this claim, in the fourth place in that an electric machine of the type described in the preamble to claim 36 is given the special features define in the characterizing part of this claim, and in the fifth place in that a vehicle of the type described in the preamble to claim 42 is given the special features defined in the characterizing part of this claim.

The invention is thus based on a special technique for constructing electric machines, motors, generators, transformers, etc. in which the electric windings are produced with dry insulation in a special manner. This permits either elimination of the transformer and/or the construction of transformers without the drawbacks inherent in conventional ones that have been mentioned above.

The drive system may include machines of various types in several phases of the power transmission from distribution network to vehicle wheels. It may naturally also include such special machines in only certain phases, combined with conventional machines.

Thus a machine of the type to which the invention relates may be arranged either to transmit electric power from the distribution network to the supply line or to transmit electric power from the supply line to the wheel axles. In the former case the machine may

be a transformer or a motor generator operating as converter. In the latter case the machine may be a transformer or a traction motor which does not then need any transformer. The alternatives may of course be combined.

The drive system and the components according to the invention can be adapted to the electric supply system of various railway systems and, with applicable modifications, is intended for railway systems with external power supply or with their own power supply system, for railways with different voltage levels and different frequencies and for both alternating and direct current systems, as well as for both synchronous and asynchronous motor operation.

The various aspects of the invention can be considered as relating to the total system, to the distribution system and to the vehicle.

The following provides an explanation of a number of the benefits offered by the invention. Advantages relating particularly to certain preferred embodiments are also pointed out. A number of additional particularly preferred embodiments are also defined in the dependent claims, claims 2-16 relating especially to advantageous embodiments of the actual machines in the system.

In cases when a transformer is deemed necessary, it is an object of the present invention that the transformer shall be manufactured using a cable of the same type and in corresponding manner as for the other electric machines included in the plant and, for instance, as stated in SE-A-9700335-4.

The advantage gained by satisfying the above objects is the avoidance of an intermediate, oil-filled transformer, the reactance of which otherwise consumes reactive power. Advantages are also gained in network quality since rotating compensation exists. With a plant according to the invention the overload capacity is increased which, with the invention may be +100 %. The control area is larger than existing technology.

To achieve this, the magnetic circuit and its conductors in at least one of the electric machines included in the plant are produced with threaded permanently insulated cable and included earth. "Plant" here refers both to the part of the electric network supplying the supply line for the railway and also the part in the locomotive or motor coach that collects voltage from the supply line.

The major and essential difference between known technology and the embodiment according to the invention is thus that this is achieved with a magnetic circuit included in at least one of the machines in

the electric plant, which is arranged to be directly connected via breakers and isolators to a high supply voltage, up to between 20 and 800 kV, preferably higher than 36 kV. The magnetic circuit thus comprises one or more laminated cores with a winding consisting of a threaded cable having one or more permanently insulated conductors having a semiconducting layer both at the conductor and outside the insulation, the outer semiconducting layer being connected to earth potential.

To solve the problems arising with direct connection of electric machines, both rotating and static machines, to all types of high-voltage power networks, at least one machine in the plant according to the invention has a number of features as mentioned above, which differ distinctly from known technology. Additional features and further embodiments are defined in the dependent claims and are discussed in the following.

The features mentioned above and other essential characteristics of the plant and at least one of the electric machines included therein according to the invention, include the following:

- The winding for the magnetic circuit is produced from a cable having one or more permanently insulated conductors with a semiconducting layer at both conductor and sheath. Some typical conductors of this type are PEX cable or a cable with EP rubber insulation which, however, for the present purpose are further developed both as regards the strands in the conductor and the nature of the outer sheath. PEX = crosslinked polyethylene (XLPE). EP = ethylene propylene.

- Cables with circular cross section are preferred, but cables with some other cross section may be used in order to obtain better packing density, for instance.

- Such a cable allows the laminated core to be designed according to the invention in a new and optimal way as regards slots and teeth.

- The winding is preferably manufactured with insulation in steps for best utilization of the laminated core.

- The winding is preferably manufactured as a multi-layered, concentric cable winding, thus enabling the number of coil-end intersections to be reduced.

- The slot design is suited to the cross section of the winding cable so that the slots are in the form of a number of cylindrical openings running axially and/or radially outside each

other and having an open waist running between the layers of the armature winding.

- The design of the slots is adjusted to the relevant cable cross section and to the stepped insulation of the winding. The stepped insulation allows the magnetic core to have substantially constant tooth width, irrespective of the radial extension.

- The above-mentioned further development as regards the strands entails the winding conductors consisting of a number of impacted strata/layers, i.e. insulated strands that from the point of view of an electric machine, are not necessarily correctly transposed, uninsulated and/or insulated from each other.

- The above-mentioned further development as regards the outer sheath entails that at suitable points along the length of the conductor, the outer sheath is cut off, each cut partial length being connected directly to earth potential.

The use of a cable of the type described above allows the entire length of the outer sheath of the winding, as well as other parts of the plant, to be kept at earth potential. An important advantage is that the electric field is close to zero within the coil-end region outside the outer semiconducting layer. With earth potential on the outer sheath the electric field need not be controlled. This means that no field concentrations will occur either in the core, in the coil-end regions or in the transition between them.

The mixture of insulated and/or uninsulated impacted strands, or transposed strands, results in low stray losses.

The cable for high voltage used in the magnetic circuit winding is built up of an inner core/conductor with a plurality of strands, at least one semiconducting layer, the innermost being surrounded by an insulating layer, which is in turn surrounded by an outer semiconducting layer having an outer diameter in the order of 10-250 mm and a conductor area in the order of 40-3000 mm^2.

If at least one of the machines in the plant according to the invention is constructed in the manner specified, start and control of the motor(s) used in the locomotive of motor coach can be achieved with the start methods, known per se, described by way of example in the literature discussed in the introduction.

According to a particularly preferred embodiment of the invention, at least two of these layers, preferably all three, have the same coefficient of thermal expansion. The decisive benefit is thus

gained that defects, cracks and the like are avoided during thermal movement in the winding.

In another aspect of the invention, the object stated has been achieved in that a system of the type described in the preamble to claim 28 is given the special features defined in the characterizing part of this claim.

Since the insulation system, suitably permanent, is designed so that from the thermal and electrical point of view it is dimensioned for over 36 kV, the system can be connected to high-voltage power networks without any intermediate step-down transformer, thereby achieving the advantages referred to above. Such a system is preferably, but not necessarily, constructed to include the features defined for system as claimed in any of claims 1-27.

The above-mentioned and other advantageous embodiments of the invention are defined in the dependent claims.

Brief description of the drawings:

The invention will be described in more detail in the following detailed description of a preferred embodiment of the construction of the magnetic circuit of an electric machine in the plant, with reference to the accompanying drawings in which

Figure 1 shows a schematic axial end view of a sector of the stator in an electric machine in the plant according to the invention,

Figure 2 shows an end view, step-stripped, of a cable used in the winding of the stator according to Figure 1,

Figure 3 shows a basic circuit for the supply of traction motors in railway operation according to known technology,

Figure 4 shows a basic circuit corresponding to that shown in Figure 3, for supply of traction motors in railway operation according to the present invention, and

Figure 5 shows a basic circuit for an alternative embodiment for the supply of traction motors in railway operation according to the present invention,

Description of a preferred embodiment:

In the schematic axial view through a sector of the stator 1 according to Figure 1, pertaining to an electric machine of rotating type included in the plant according to the invention, the rotor 2 of the machine is also indicated. The stator 1 is composed of a laminated core in conventional manner. Figure 1 shows a sector of the machine corresponding to one pole pitch. From a yoke part 3 of the core situated radially outermost, a number of teeth 4 extend radially in towards the rotor 2 and are separated by slots 5 in which the stator winding is arranged. Cables 6 forming this stator winding, are high-voltage cables which may be of substantially the same type as those used for power distribution, i.e. PEX cables. One difference is that the outer, mechanically-protective sheath, and the metal screen normally surrounding such power distribution cables are eliminated so that the cable for the present application comprises only the conductor and at least one semiconducting layer on each side of an insulating layer. Thus, the semiconducting layer which is sensitive to mechanical damage lies naked on the surface of the cable.

The cables 6 are illustrated schematically in Figure 1, only the conducting central part of each cable part or coil side being drawn in. As can be seen, each slot 5 has varying cross section with alternating wide parts 7 and narrow parts 8. The wide parts 7 are substantially circular and surround the cabling, the waist parts between these forming narrow parts 8. The waist parts serve to radially fix the position of each cable. The cross section of the slot 5 also narrows radially inwards. This is because the voltage on the cable parts is lower the closer to the radially inner part of the stator 1 they are situated. Slimmer cabling can therefore be used there, whereas coarser cabling is necessary further out. In the example illustrated cables of three different dimensions are used, arranged in three correspondingly dimensioned sections 51, 52, 53 of slots 5.

The above description of the magnetic circuit for a rotating electric machine built up with the cable 6 is also applicable to static electric machines such as transformers, reactor windings and the like. The following important advantages are obtained both from the design and the manufacturing point of view:

- the windings of the transformer can be constructed without consideration to any electric field distribution and the problematical transposition of parts in known technology is thus unnecessary,

- the transformer core can be designed without taking into consideration any electric field distribution,
- no oil is required for electric insulation of cable and winding and instead the cable and winding can be surrounded by air,
- no special bushing is required as is the case for oil-filled transformers, for electrical communication between the outer connections of the transformer and the coils/windings located therein, and
- the manufacturing and testing technology required for a dry transformer with magnetic circuit as described above, is considerably simpler that is required for conventional transformers/reactors.

Figure 2 shows a step-wise stripped end view of a high-voltage cable for use in an electric machine included in the plant according to the present invention. The high-voltage cable 6 comprises one or more conductors 31, each of which comprises a number of strands 36 which together give a circular cross section of copper (Cu), for instance. These conductors 31 are arranged in the middle of the high-voltage cable 6 and are surrounded in the embodiment shown by a part insulation 35. However, it is feasible for the part insulation 35 to be omitted on one of the conductors 31. In the present embodiment of the invention the conductors 31 are together surrounded by a first semiconducting layer 32. Around this first semiconducting layer 32 is an insulating layer 33, e.g. PEX insulation, which is in turn surrounded by a second semiconducting layer 34. Thus the concept "high-voltage cable" in this application need not include any metallic screen or outer sheath of the type that normally surrounds such a cable for power distribution.

The use of electric machines provided with magnetic circuits of the type described above enables the electric supply of traction motors, as well as the traction motors themselves, to be greatly simplified and made more efficient. In railway operation with alternating voltage the supply voltages currently used are generally 16 kV, $16^2/3$ or 25 Hz, 50 Hz in the supply line 104 from which the locomotive 110 via its current collector 112 supplies one or more traction motors 114, as shown in Figure 3.

For supply of the supply line 104, this known supply plant requires a transformer 101 in order to step down the voltage from a general 3-phase distribution network 100, e.g. for voltages of 130 or 220 kV, 50 or 60 Hz, to 16 or 25 kV, 50 or 60 Hz. A converter 102

is also required to convert the voltage to 1-phase and, in the case with 16 kV to $16^2/3$ Hz, to be fed out on the railway supply line 104.

Known traction motors 114 for alternating voltage are normally driven by voltages of up to 1 kV and the locomotive 110 must therefore be equipped with a transformer 113 and with speed-control equipment, the latter constituting thyristors in modern locomotives.

The transformers 101 and 113 used in the known plant are oil-filled and have a number of mechanical and electrical drawbacks, as well as incurring environmental problems. The rotating machines 102 and 114 used for converting and operation in the known plants have various problems, both mechanical and electrical, that can be dealt with to a more or less satisfactory extent.

The above-mentioned problems can be eliminated, or at any rate minimized, by designing the magnetic circuits in at least one of the electric machines included in the plant, in accordance with the present invention.

According to one embodiment of the plant according to the invention, the voltage for the supply line 104 is provided by a motor generator 105, driven directly from the 3-phase distribution network 100 with no intermediate transformer. The motor generator 105 comprises a 3-phase motor 106 connected directly to the distribution network 100, the magnetic circuit of the motor being formed in the manner described above with reference to Figures 1 and 2. The shaft 107 of the electric 3-phase motor is common to a generator 108 belonging to the motor generator 105 and thus driven by the 3-phase motor. The magnetic circuit of the generator 108 is suitably built up in the same way as described with reference to Figures 1 and 2 (but need not necessarily have this design). The generator 108 supplies the voltage type used on the railway supply line 104.

Conventional locomotives and motor coaches 110 may be used for supplying the supply line 104 from the generator 108. However, further significant advantages are obtained with locomotives or motor coaches equipped with one or more traction motors 115 (Figure 4), with magnetic circuits designed in accordance with the description with reference to Figures 1 and 2. Such a traction motor 115 is thus driven directly from the supply line 104 without any intermediate transformer or thyristor control. Over and above the advantages already mentioned, therefore, this also offers the

significant advantage of reduced weight for the locomotive/motor coach, and consequently improved economy for the railway company.

Another embodiment of the plant shown in Figure 4 is revealed in Figure 5 where the same motor generator 105 supplies the railway supply line 104. The locomotive/motor coach 110, however, is here equipped with a dry transformer 116 of the type described above with reference to Figure 1, which supplies a conventional traction motor 114.

Although certain voltage values have been noted above and on the drawings, these shall only be considered as examples. Similarly, various combinations of conventionally designed electric machines and electric machines provided with the magnetic circuit according to the invention are feasible in the plant according to the present invention. The invention shall not therefore be deemed as restricted to the plants described with reference to the drawings, but covers all feasible plants defined in the appended claims.

CLAIMS

1. An electric drive system for driving vehicles, e.g. railway locomotives and motor coaches, in which electric power is transferred from a distribution network via an overhead conductor and at least one traction motor to the mechanical drive shafts of the vehicle, the system comprising at least one electric machines arranged between the distribution network and the drive shafts, each electric machine having at least one winding, characterized in that at least one of said machines has a winding comprising an insulation system consisting of at least two semiconducting layers, each layer constituting essentially an equipotential surface, and solid insulation between them.

2. A drive system as claimed in claim 1, characterized in that at least one of said layers has substantially the same coefficient of thermal expansion as the solid insulation.

3. A drive system as claimed in claim 1, characterized in that said at least one machine comprises a magnetic circuit with a magnetic core.

4. A drive system as claimed in claim 3, characterized in that the flux paths in the core of the magnetic circuit in said at least one machine (105, 116) in the plant consists of laminated sheet plate and/or rough forged iron and/or cast iron and or powder-based iron.

5. A drive system as claimed in any of claims 1-4, characterized in that the solid insulation is built up of a cable (6) intended for high voltage, comprising one or more current-carrying conductors (31) surrounded by at least two semiconducting layers (32, 34) with intermediate insulating layers (33) of solid insulation.

6. A drive system as claimed in claim 5, characterized in that the innermost semiconducting layer (32) is at substantially the same potential as the conductor(s) (31).

7. A drive system as claimed in either claim 5 or claim 6, characterized in that one of the outer semiconducting layers (34) is arranged to form essentially an equipotential surface surrounding the conductor(s) (31).

8. A drive system as claimed in claim 6, characterized in that said outer semiconducting layer (34) is connected to a selected potential.

9. A drive system as claimed in claim 8, characterized in that the selected potential is earth potential.

10. A drive system as claimed in any of claims 5-7, characterized in that the current-carrying conductor comprises a plurality of strands, only a few of the strands not being insulated from each other.

11. A drive system as claimed in any of claims 1-10, characterized in that the winding consists of a cable comprising one or more current-carrying conductors (2), each conductor consisting of a number of strands, an inner semiconducting layer (3) being arranged around each conductor, an insulating layer (4) of solid insulation being arranged around each inner semiconducting layer (3) and an outer semiconducting layer (5) being arranged around each insulating layer (4).

12. A drive system as claimed in claim 11, characterized in that the cable also comprises a metal screen and a sheath.

13. A drive system as claimed in any of the preceding claims, characterized in that the magnetic circuit contains air or other insulating gases.

14. A drive system as claimed in claim 3, characterized in that the winding(s) of the magnetic circuit, and also the permanently insulated connection conductors for high tension current between the system units are produced using a cable (6) with solid insulation for high voltage and comprising at least two semiconducting layers (32, 34), and also strands (36) which may be insulated or uninsulated.

15. A drive system as claimed in either claim 5 or claim 14, characterized in that the high-voltage cables (6) have a conductor area of between 30 and 3000 mm^2 and have an outer cable diameter of between 10 and 250 mm.

16. A drive system as claimed in any of the preceding claims, characterized in that the outer semiconducting layer (34) is connected to earth potential.

17. A drive system as claimed in any of the preceding claims, characterized in that the winding of at least one of said machines is arranged for self-regulating field control and lacks auxiliary means for control of the field.

18. A drive system as claimed in any of the preceding claims, characterized in that one of said at least one of said

machines is arranged between the distribution network and the supply line.

19. A drive system as claimed in claim 18, characterized in that said machine is a transformer for step-down transforming from the voltage level of the distribution network to the voltage level of the overhead conductor.

20. A drive system as claimed in claim 18, characterized in that said machine is a motor generator in which the motor is supplied with the voltage of the distribution network and the generator emits a voltage corresponding to the voltage level of the supply line.

21. A drive system as claimed in claim 20, characterized in that the rotor shaft of the motor is connected directly to the generator shaft.

22. A drive system as claimed in claim 20 or claim 21, characterized in that the generator is of single-phase type.

23. A drive system as claimed in claim 22, characterized in that the frequency of the is an integer part of the network frequency, preferably $16^2/3$, 20 or 25 Hz.

24. A drive system as claimed in any of the preceding claims, characterized in that at least one of said at least one machine is arranged in the vehicle.

25. A drive system as claimed in claim 24, characterized in that said at least one machine arranged in the vehicle is a transformer for step-down transformation of the voltage of the overhead conductor to the voltage of the traction motor.

26. A drive system as claimed in claim 24, characterized in that the at least one machine arranged in the vehicle is at least one traction motor in the vehicle.

27. A drive system as claimed in claim 26, characterized in that said at least one traction motor is supplied directly with voltage from the supply line without intermediate connection of another electric machine.

28. An electric drive system for driving vehicles, e.g. railway locomotives and motor coaches, in which electric power is transferred from a distribution network via an overhead conductor and at least one traction motor to the mechanical drive shafts of the vehicle, the system comprising at least two electric machines arranged between the distribution network and the drive shafts,

each electric machine having at least one winding, characterized in that at least one of said machines has a winding comprising an insulation system which, as regards its thermal and electrical properties, permits a voltage level in the machine in excess of 36 kV.

29. An electric drive system as claimed in claim 28, characterized in that the machine includes the features defined in any of claims 1-27.

30. An electric power transmission means between a distribution network and an overhead conductor intended for electrically operated vehicles, comprising an electric machine provided with at least one winding, characterized in that the winding comprises an insulation system comprising at least two semi-conducing layers, each layer constituting essentially an equipotential surface, and solid insulation therebetween.

31. A means as claimed in claim 30, characterized in that the machine is a transformer for step-down transforming from the voltage level of the distribution network to the voltage level of the overhead conductor.

32. A means as claimed in claim 31, characterized in that the machine is a motor generator in which the motor is supplied with the voltage of the distribution network and the generator emits a voltage corresponding to the voltage level of the overhead conductor.

33. A means as claimed in claim 32, characterized in that the motor generator comprises the features defined for the motor generator claimed in any of claims 22-24.

34. A means as claimed in either of claims 31-32, characterized in that the machine comprises the features defined for said at least one of the machines in any of claims 2-17.

35. A procedure for transmitting electric power from a distribution network to an overhead conductor intended for electrically powered vehicles, characterized in that the electric power is transmitted by a means as claimed in any of claims 30-34.

36. An electric machine in a vehicle such as a railway locomotive or a motor coach, in which the electric power is obtained from an overhead conductor, said machine being arranged to transmit the electric power from the overhead conductor to the

drive shafts of the vehicle, and said machine being provided with at least one winding, characterized in that the winding comprises an insulation system consisting of at least two semiconducting layers, each layer constituting essentially an equipotential surface, and solid insulation between them.

37. An electric machine as claimed in claim 36, characterized in that the machine is a transformer for step-down transformation of the voltage of the overhead conductor to the voltage of a traction motor in the vehicle.

38. An electric machine as claimed in claim 37, characterized in that the transformer is cooled at earth potential.

39. An electric machine as claimed in claim 36 or claim 38, characterized in that the magnetic circuit of the transformer is of core or shell type.

40. An electric machine as claimed in claim 36, characterized in that the machine is a traction motor connected to the overhead conductor without an intermediate transformer.

41. An electric machine as claimed in any of claims 36-40, characterized in that the machine includes the features defined for said at least one machine claimed in any of claims 2-17.

42. An electrically powered vehicle which obtains driving power from an overhead conductor, characterized in that the vehicle is provided with at least one machine as claimed in any of claims 36-41.

Fig.1

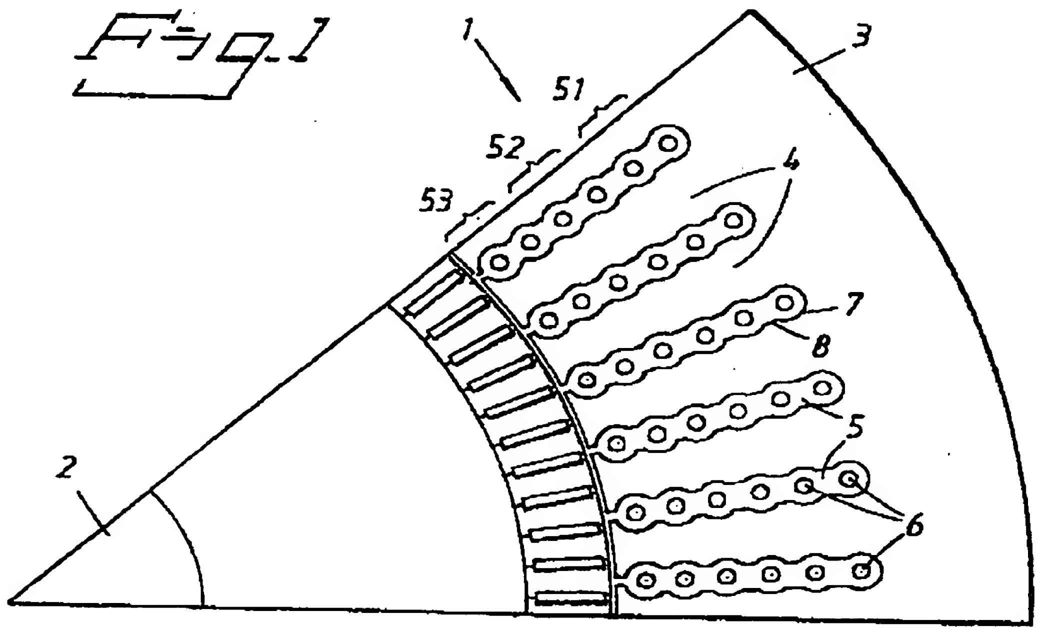

Fig.2

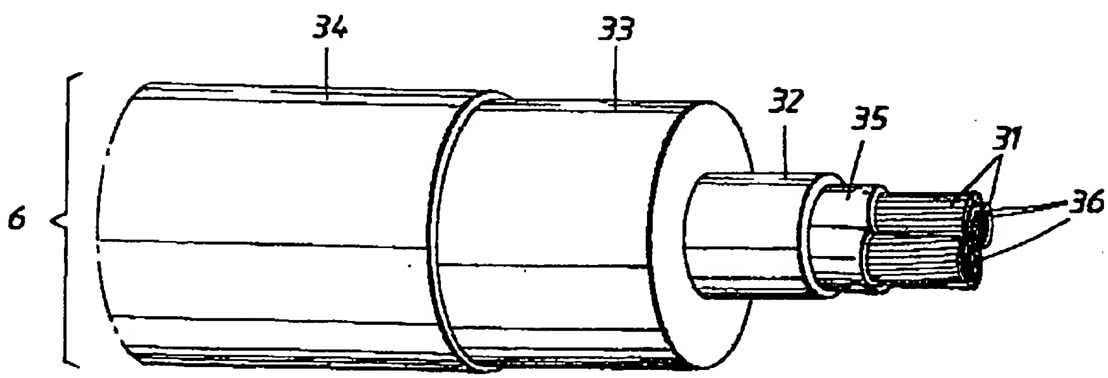

Fig-3

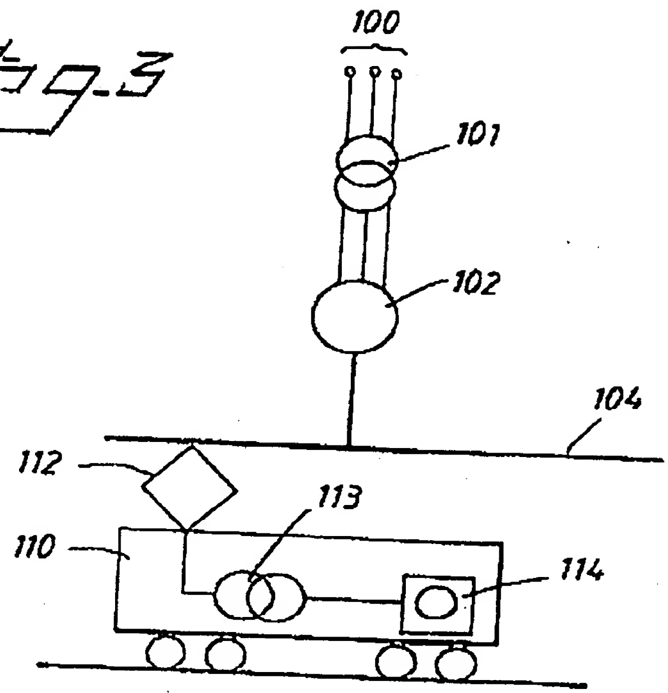
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Fig-4

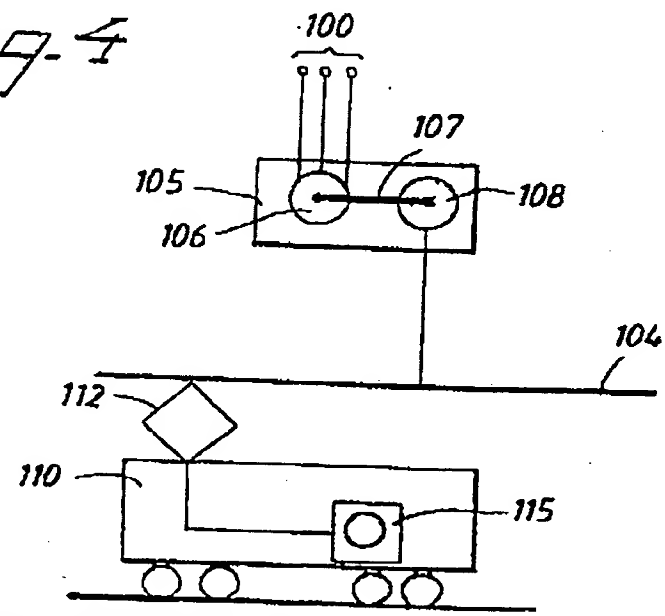
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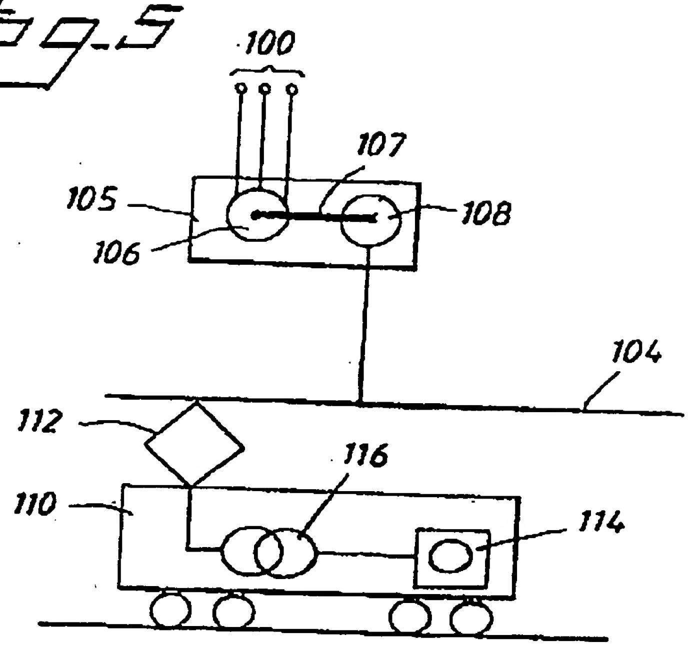
Fig. 5



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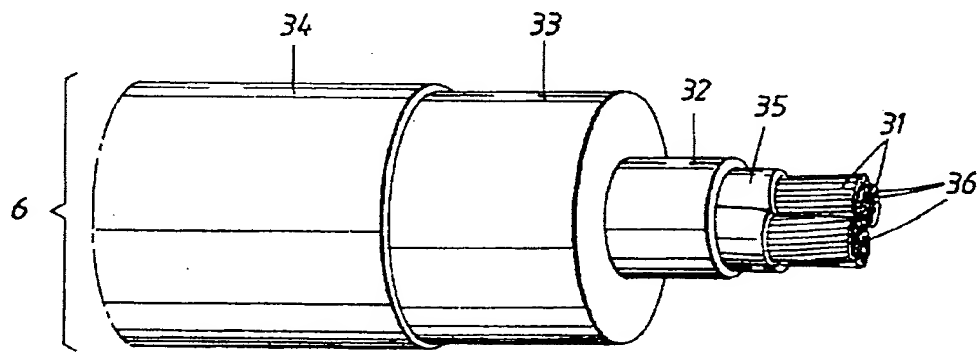

(57) Abstract

In a plant intended for driving traction motors e.g. railway locomotives or motor coaches, and which possibly comprises one or more electric machines provided with insulated conductors, the magnetic circuit in the traction motor(s) and/or in at least one of the other electric machines is connected directly to a high supply voltage of 21-800 kV, preferably higher than 36 kV. The insulation in each traction motor and other electric machines is built up of a cable (6) forming its winding, said cable (6) comprising one or more current-carrying conductors (31) with a number of strands (36), surrounded by at least two semiconducting layers (32, 37) and intermediate insulating layers (36). The traction motor(s) may be connected to the distribution network supplying the supply line of the railway without any other electric machine connected between, or via one or more of said other electric machines. The locomotive/motor coach may thus be constructed with only traction motor(s) without any other electric machine.

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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 Sept 1997	18 -11- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Håkan Sandh Telephone No. + 46 8 782 25 00

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International application No.
PCT/SE 97/00888

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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